Hubble science without servicing

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Origins Subcommittee
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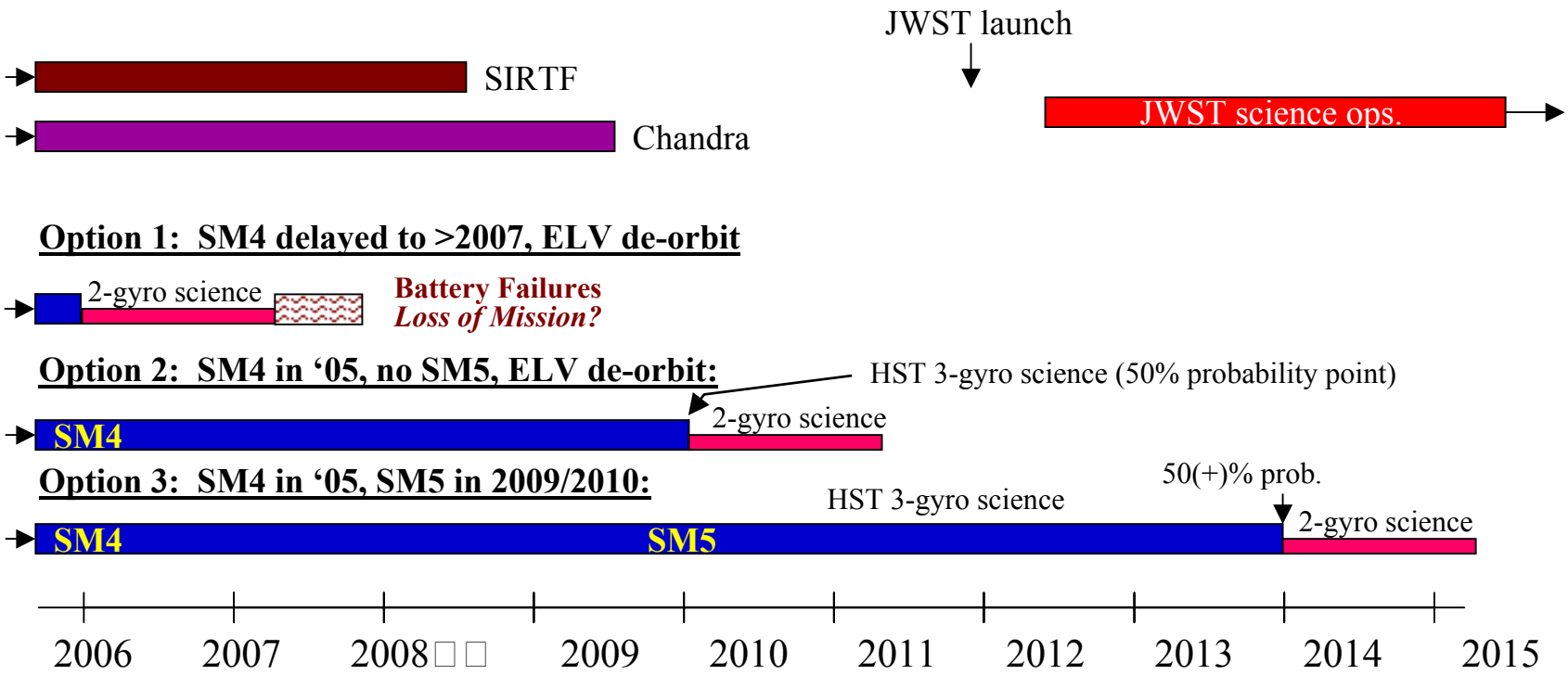
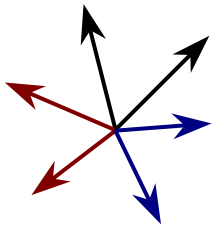
HST Servicing Options



2-gyro pointing buys about 15 months of additional science time if a 4th gyro fails.
Battery failures may limit the observatory operation, if SM4 is delayed beyond late 2005.
Reduced battery capacity could also limit us to one instrument at any time before SM4.

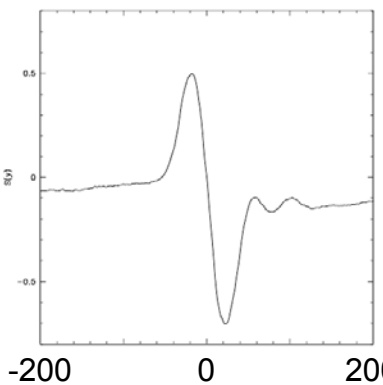
Why is 2-gyro pointing relevant to OS?

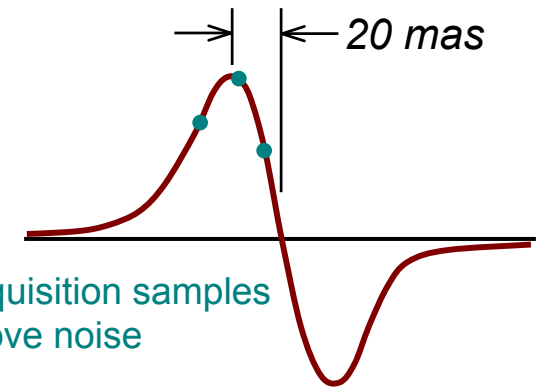
- HST's scientific lifetime depends on working gyros:
  - It currently has 4 working gyros, 3 of which are needed for science
  - Projections show a loss of two more gyros (P>50%) by 12/05
  - Pointing under 2-gyro mode will extend the science lifetime by ~15 months before losing one more gyro
- A 2-gyro pointing mode will not recover HST's full science program
  - The pointing jitter will increase with less than 3 gyros
  - We must still verify that we can acquire guide stars under 2-gyro control (PCS system under design)
  - The HST science program will have to be modified to mitigate against the pointing losses under 2-gyro control.
  - Loss of battery capacity could be the long-term limit before SM4

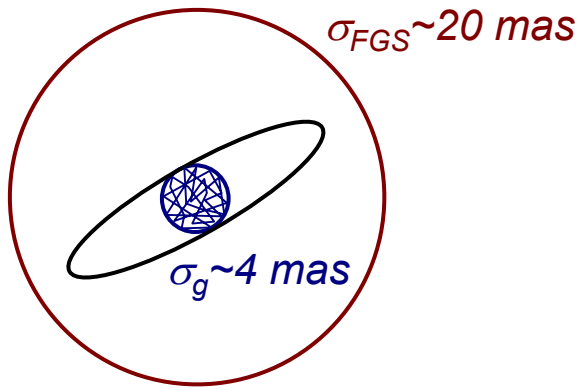


HST pointing control

- Uses gyroscopes for acquisition & pointing
  - 6 axis fully independent gyro orientation; relative angles ~60º
  - Rate sensors S/N independent of guide star magnitudes
  - Gyro sensor updates at 20-40 Hz; FGS updates averaged to 1 Hz
  - Gyro drift rate ~5″ during Earth occultation (40 minutes)
  - Floor jitter 2 - 5 mas under gyro control
- FGS "S-curve" yields inherent σ~15 - 30 mas
  - Locking depends on slow drift rate during acquisition

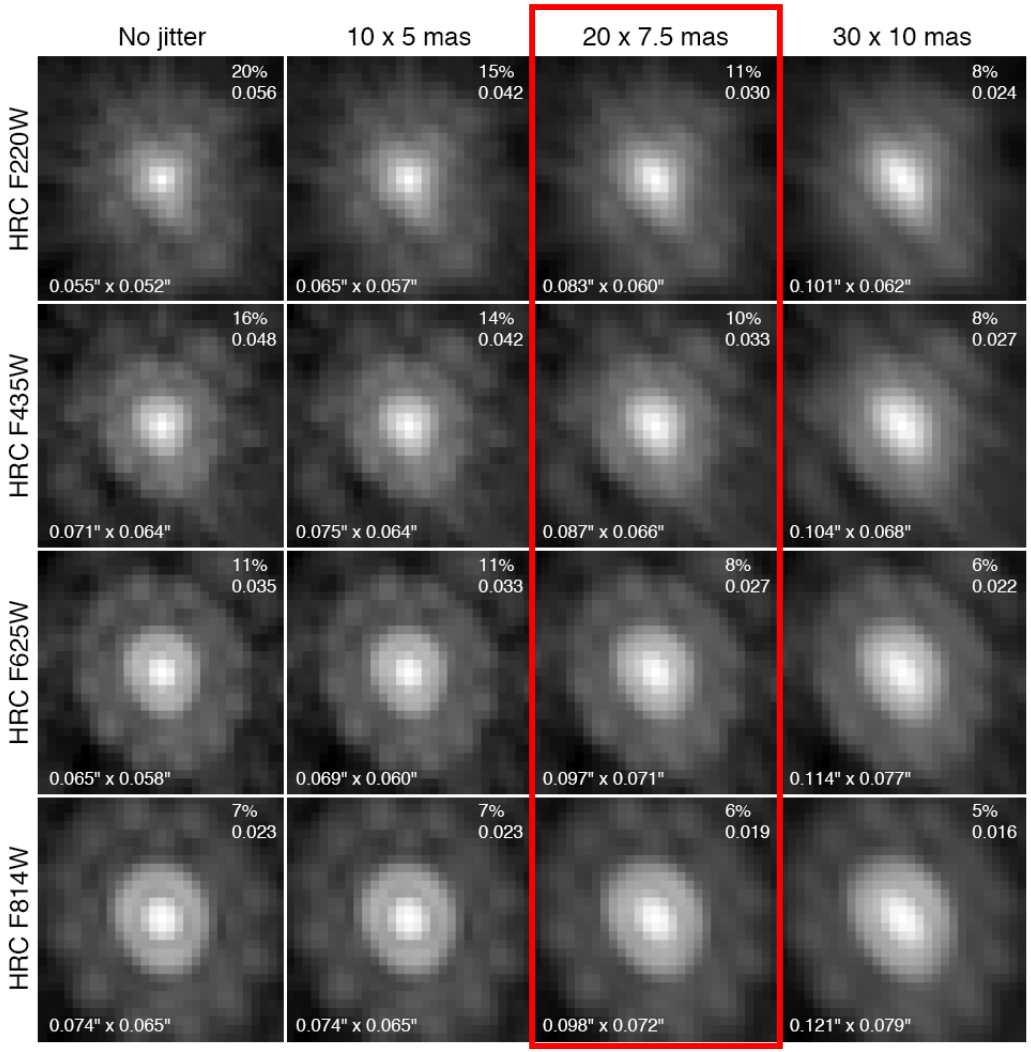






Images under 2-gyro control

PSF: $\sigma_{tot}^2 = \sigma_{intrinsic}^2 + \sigma_{jitter}^2$



- Jitter magnitude and direction depend on which gyros are alive
- Direction of elongation will change across sky
- Expected worst jitter ~15-30 mas

- HRC degraded
- WFC suffers small degradation
- Broad slits OK, narrow slits problematic

Science Implications

- Can we acquire guide stars?
  - Loss of lock & FGS S curve
  - Acquisition time (now 6 min)
- Telescope drift: degrees/slew
  - Must use FHST for pointing & rate updates
  - Reduces schedulability of any observation to <1/2

Diffraction-limited & high-contrast imaging will be severely compromised
Wide-field imaging will only suffer slightly

- BLIP means $t_{exp} \sim PSF^2$

  Exposure time increase vs. jitter

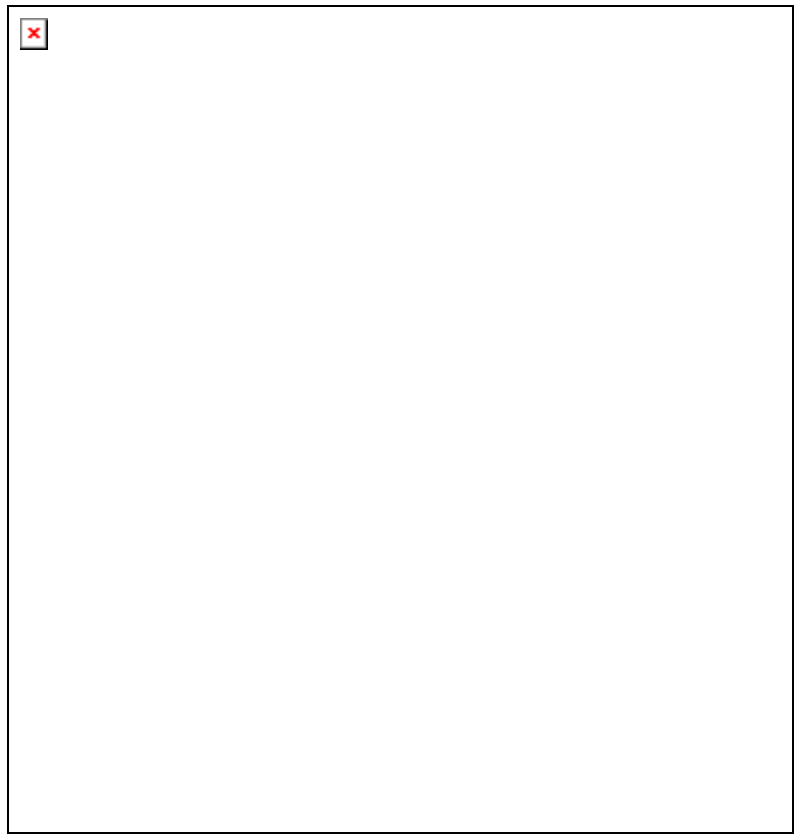
σ_{jitter}:	25	50 mas
– HRC scale	2x	7x
– WFC scale	1.3x	2x
– >WFC	1x	1.3x

- HST Science:
  - 91% Large (WFC) scale
  - 9% Small (HRC) scale
  - Instrument split:
    - ACS: 55%
    - NICMOS: 21%
    - STIS: 17%
    - WFPC2: 2%
    - FGS: 5%

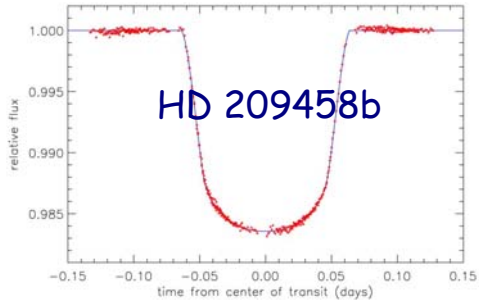
Impact on Cycle 12 Programs

The full science program requires:
1.35x exposure at σ ~ 25 mas
2.5x exposure at σ ~ 50 mas

Instrument	Aperture	%Time
ACS	Small	5.1%
	Large	**49.7%**
NICMOS	Small	3.4%
	Large	**17.6%**
STIS	Small	0.4%
	Large	**16.4%**
WFPC2	**Large**	**2.3%**
FGS	Small	5.0%
Total	*Small*	*8.5%*
	Large	***91.5%***



HST high impact science

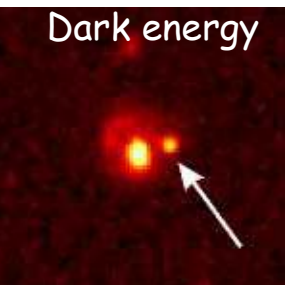


- 1st decade science
  - Distance scale: H_0
  - Black holes in galaxies
  - AGN emission lines
  - QSO host galaxies
  - IGM/ISM (QAL)

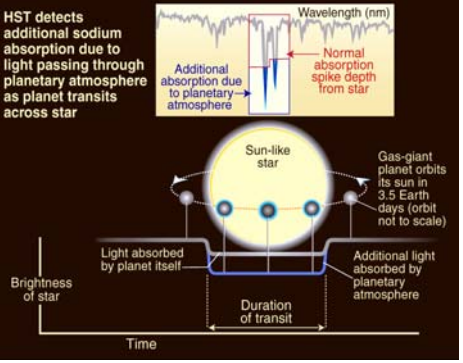
  First decade science relied on:
  - Diffraction-limited imaging over small fields
  - High-contrast optical imaging
  - Ultraviolet sensitivity

- Cycle 12 science
  - Galaxy formation: GOODS, HUDF, GEMS, COSMOS
  - Dark energy: high-z SN Ia & Λ:
  - γ-ray bursts: host galaxies
  - Planet formation: disks
  - Extra-solar planets: bulge stars

  Second decade science relies on:
  - High sensitivity over wide fields
  - High-contrast optical imaging
  - Very high photometric stability



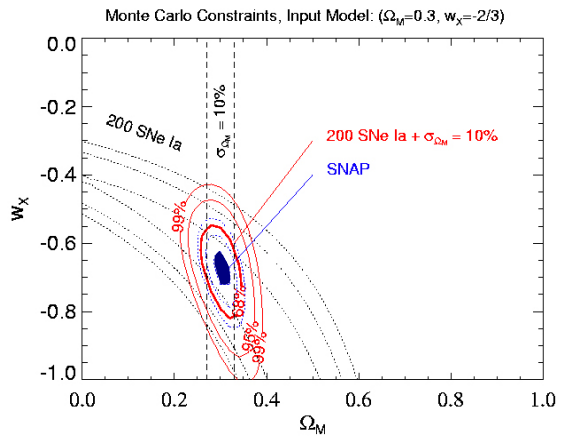
Current surveys should be possible with 2-gyro control
The science program is largely intact with 2-gyros



HST future science

- "Local" neighborhood
  - Exo-planet detection and characterization
  - Na, H_2O, CO in 5-10 exo-planet atmospheres
  - Direct imaging of exo-planets
  - Nature of MACHO sources
  - Mass of Galactic black holes
  - Star formation: Local Group
- "Distant" universe
  - Dark matter in dwarf spheroidals
  - Tests of galaxy-halo formation
  - Reverberation mapping near BH event horizons
  - Large-scale structure of the IGM
  - Galaxy formation in clusters to z~8
  - Weak lensing of dark matter halos
  - What is dark energy?

Diffraction-limited & high-contrast imaging will become increasingly important to HST future science, ideally over wide fields
Future science will be compromised with 2-gyros



Summary: HST 2-gyro pointing

- A 2-gyro mode can buy HST ~15 months science lifetime if servicing is delayed (SM4)
- The *current* science program stresses wide-field science that can be carried out under 2-gyro control
- *Future* science programs will increasingly stress diffraction-limited and high-contrast imaging that cannot be done under 2-gyro control

A 2-gyro control mode for HST *is a prudent way* to mitigate against unforeseen delays in future servicing of HST

It is *not* a substitute for the scientific capabilities of HST pointing under 3-gyro control